Electrooptic Propagation

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LONG TERM GOALS

Provide a quantitative description of the propagation environment for EO (visible and IR) energy within the marine and coastal environments through models and measurements.

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OBJECTIVES

The EO Propagation objectives are threefold: 1) investigate, develop and evaluate ocean and coastal aerosol models and their effects on IR propagation, 2) investigate and develop simple, realistic models for infrared propagation near the ocean surface, and 3) develop, evaluate, and improve software models that assess and predict EO systems performance in marine tactical scenarios.

APPROACH

Remote (surface-based and satellite) and in-situ (surface and airborne) sensors are to be used to measure the optical and meteorological parameters from which models of aerosol-size distributions and sky/sea/terrain backgrounds can be developed and evaluated. This involves both the development and evaluation of aerosol/radiance models capable of predicting optical/IR propagation in the marine atmosphere.

WORK COMPLETED

MARINE AEROSOL MEASUREMENTS AND MODELING

The initial version of ANAM (Advanced Navy Aerosol Model) was completed and is being evaluated.

SSC led the planning and conducting of two measurement and aerosol modeling IOPs as follows:

1) the advection of surf produced aerosol, Duck, NC, February 1998;
2) the ANAM validation campaign, North Sea, June 1998.

An initial analysis of the NRL lidar and SSC aerosol data taken at the Duck IOP has been completed. All the aerosol and meteorology data for the ANAM validation has been reduced and made available to all participants and the initial analysis is under way.

The statistical analysis of three techniques (radon, CN, and nephelometer measurements) for determining the air mass parameter for aerosol modeling has been completed.

The evaluation of a technique for inferring boundary layer air mass parameters from satellite upwelling radiance measurements utilizing extended lidar and aircraft in-situ data sets has been completed and presented at three conferences.

The analysis of the maritime stratus-cloud aerosol-size-distributions database and the development of an aerosol model beneath maritime stratus clouds have been completed.

Nine conference papers and technical reports were prepared and are listed in the Publications section.

IR TRANSMISSION AND RADIANCE

A new black body source and field lenses were installed in the long and mid-wave transmitter and receiver, respectively. Low altitude transmission data across San Diego Bay were collected for three weeks in May and June. A beam splitter was used to mount the long and mid-wave detectors on a single receiver, providing identical paths for correlating the optical scintillation in each band. Scintillation data were collected for three weeks during September. Professor Gudimetla developed and

reported a theory for the scintillation of a thermal source. The Cox-Munk model of ocean radiance, previously extended by Zeisse, was further developed to provide an expression for infrared reflectivity at grazing angles.

A manuscript entitled "Infrared Radiance of the Wind Ruffled Sea" was submitted to the Journal of the Optical Society of America. Two talks were given, three papers were presented at conferences, and an internal report was produced (References for these reports are listed under "Publications").

SYSTEMS PERFORMANCE ASSESSMENT

The SeaRad ocean radiance model was combined with a more precise sky model. The analysis of the new model was completed and a final report issued. Calibrated coastal ocean radiance data, supplemented with meteorological support from the SIO/ONR buoy, was used to investigate the ocean radiance and clutter algorithms in IRTool. IRTool predictions in the long-wave IR band were compared with the SeaRad model and the results were presented at the 1998 International SPIE meeting. Data collection has begun for future evaluation of the mid-wave IR band, and comparison of new IRTool based ocean radiance models is being developed.

RESULTS

MARINE AEROSOL MEAUREMENTS AND MODELING

Near ocean surface aerosols and the impact of surf were again the primary objectives for the aerosol measurements and modeling effort during this fiscal year. Previous analyses of the EOPACE database indicated that the surf-produced aerosol cloud is not uniform as it might appear visually. This was dramatically verified by the use of the NRL lidar at Duck, NC. The initial results of these measurements showed that, under the conditions of surf-produced aerosol being advected seaward by the ambient wind, plume like clouds of large marine aerosol were being advected seaward to distances of several kilometers. In this experiment, simultaneous and co-located measurements, i.e., lidar, in-situ aerosol size distributions, and meteorology data can be used to calibrate the lidar backscatter returns.

The utilization of the MAPTIP aerosol database for the development of ANAM confirmed the existence of an aerosol mode resulting from wave/wind generated aerosols near the ocean surface. The subsequent extensive data analysis, evaluation, and development have resulted in an initial near ocean aerosol model ANAM (Advanced Navy Aerosol Model) being completed.

The development and evaluation of ANAM included several aspects. Firstly, the size distribution profiles that were predicted by the initial ANAM have been augmented with the addition of internal Mie calculations by which the electrooptic properties of the region may be described. Secondly, a new approach to overcoming the complexity of gathering additional empirical data to verify and extend the ANAM model is being undertaken by utilizing the French and Dutch numerical model SEACLUSE. This model is being operated simultaneously with ANAM for model parameterization. The experiments include model simulations of situations where actual field data is available for comparisons with the modeled output. Also, the experiment includes situations where no field data are available but where only ANAM predictions exist. In the later case, verification and improvements of the ANAM are expected.

During the EOPACE IOP#7, the air mass parameter was inferred from three different techniques utilizing radon, CN, and nephelometer measurements. A statistical analysis comparing these three techniques was completed. Results showed that the nephelometer technique for air mass parameter inference was the most practical.

The technique for inferring the boundary layer air mass parameter from satellite upwelling radiance measurements was presented at the 1998 SPIE meeting, San Diego, CA, July 1998, and at the 5th International Aerosol Conference, Edinburgh, Scotland, September 1998. This technique shows promise and is being expanded to investigate the effects of elevated layers and particle entrainment.

An aerosol model has been developed for use in computer codes to describe the optical propagation of the far infrared (IR) wavelength band in maritime stratus regimes. In the model, the wavelength dependent IR extinction and absorption coefficients (normalized to the 0.55 μm extinction coefficient) and the asymmetry factors are described by multiplying arrays compatible with the MODTRAN input format for four different regions of the stratus regime. The model has been used with a modified version of MODTRAN (SEARAD) to test its utility in system performance predictions beneath these types of clouds. The calculations with the model provided nearly a factor of 3 better agreement with observation of the maximum detection range of a surface target by an operational airborne FLIR system than did those calculated using the stratus cloud model in MODTRAN with the Navy Aerosol Model (NAM) beneath the cloud.

IR TRANSMISSION AND RADIANCE

Transmission

The measurements/analysis of transmission data show that refractive effects are relatively rare for paths on the order of 10 km in length, and that, when they do occur, last less than about one minute. Therefore, when transmission data are averaged over a ten-minute period, molecular predictions (via MODTRAN) and aerosol measurements successfully explain the observed transmission (when the humidity is low or moderate). When the humidity is very high, however, MODTRAN under-predicts the clear air transmission. The analysis is being refined to see whether this under-prediction is significant in the light of our instrumental accuracy.

Turbulence

Values of the refractive index structure parameter, C_n^2, derived via Monin-Obukov similarity theory have been compared with those values derived from optical scintillation measurements. For our transmissometer, aperture averaging reduces the strength of the scintillation by an order of magnitude, a fact that must be taken into account when making this comparison. The comparison has shown that good agreement under unstable conditions (air cooler than the sea), very poor agreement under neutral conditions (air at the same temperature as the sea) and fair agreement under stable conditions (air warmer than the sea). Poor agreement in neutral conditions is just what would be expected from an analysis based on the Bowen ratio, and nothing further can be done about it. We hope that our comparison will foster the development of an improved bulk theory in the stable regime.

The mid wave scintillation of a thermal (black body) source is about 10% smaller than the scintillation of a coherent (laser) source for a path length of 7 km.

Radiance

At grazing angles of incidence and reflection, ocean reflectivity is several percent at low wind speeds. This is approximately one hundred times less than predicted by the traditional theory of Cox and Munk.

SYSTEMS PERFORMANCE ASSESSMENT

Analysis of the SeaRad model combined with the MODTRAN sky model produced considerable improvement to EOTDA ocean background predictions. A final report documented the improvements and SeaRad was given to NRL Monterey for inclusion in the fleet WIN-EOTDA. Although SeaRad solved inaccuracies in the current EOTDA, SeaRad was found unsuitable for use in the joint Air Force/Navy Target Acquisition Weather Software (TAWS) because it does not include scene visualization, mid-wave IR, ocean clutter or other surface atmospheric effects. IRTool was the only model found that already contained these capabilities needed for TAWS. The investigation of IRTool showed results that compared favorably with the SeaRad model and with actual near-horizon measurements. However, as a first-principles physics-based model, IRTool was found too computationally intensive for direct application as a TDA, so a new hybrid statistical, parametric, and empirical model based on IRTool has been proposed. These results were reported in the proceedings of the International SPIE meeting.

IMPACT/APPLICATIONS

Rigorous physical models of background radiance and near ocean surface transmission characteristics are lacking for the marine and coastal environment. Radiance and transmission models are required to evaluate the fidelity of approximate models that may find use in operational assessment systems. The models from this project are applicable to sensor performance assessment systems and sensor/system development projects.

TRANSITIONS

The SeaRad ocean radiance model has been transitioned to the fleet WIN-EOTDA. Data collected in collaboration with EOPACE are shared with those investigators and are utilized by them in their projects.

RELATED PROJECTS

This project is related to NRL Monterey's mesoscale and data assimilation model projects and their program for improving the current WIN-EOTDA used by the fleet in the Tactical Environmental Support System, Next Century (TESS(NC)) and the joint Air Force/Navy Target Acquisition Weather Software (TAWS) currently under development by the Air Force Research Laboratory (AFRL), the COVAMP project, and the EO-IR Senior Diagnostic work (ONR 313). Tri service coordination is conducted under the Technology Area Review and Assessment.

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